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(54) Title: VOLUMETRIC PHASED ARRAY ANTENNA SYSTEM

(57) Abstract

A volumetric phased array antenna system comprising a number of antenna elements, each of which is connected to a T/R (transmitter/receiver) module, being under the control of a beam steering computer (BSC), to which T/R module a transmitting signal is fed for forming a transmitting beam, via which T/R modules RF signals are received and via a radar receiver are fed to a signal processing unit connected thereto. The antenna elements are arranged in mutually spaced conformal curved virtual surfaces having the same center of curvature or the same centers of curvature, with each combination of antenna elements in one or more surfaces together forming a volumetric phased array antenna or a part thereof.

Title: Volumetric phased array antenna system

The present invention relates to a volumetric phased
array antenna system whose antenna elements are spatially
arranged in three dimensions and which is often referred to
as Crow's Nest Antenna (CNA).

5   More concretely, the invention relates to a volumetric
phased array antenna system comprising a number of antenna
elements, each of which is connected to a T/R
(transmitter/receiver) module, which is under the control of
a beam steering computer (BSC), to which T/R module a

10   transmitting signal is fed for forming a transmitting beam,
and via which T/R modules RF signals are received and via a
radar receiver are fed to a signal processing unit connected
thereto.

As is the case with all antenna systems, the CNA too is

15   sensitive to interference sources, the signals from which
are received in the side lobes of the antenna pattern. In
military systems, interference signals are produced by the
enemy to make intercommunication or target position
measurements impossible. In civilian systems, such

20   interference is caused by neighboring transmitting stations
or by reflections from nearby objects.

When in the use of conventional radar antenna systems
the location of the interference source is not known, use
can be made, for the purpose of suppressing such

25   interference or limiting the interference level, of
so-called adaptive nulling systems, whereby one or more
auxiliary antennas are arranged close to the main antenna.
If one interference source is present, one auxiliary antenna
is sufficient. The pattern of the main antenna is formed by

30   a strong main lobe and a large number of weak side lobes;
the antenna pattern of the auxiliary antenna is formed by a
broad lobe which extends over at least the whole angular
interval of the pattern of the main antenna, that is, over
the entire field of view of the main antenna, but has a

35   strength much smaller than that of the main lobe of the

pattern of the main antenna. In the case of a sufficiently
strong interference source, the interference signals
received via the side lobes of the pattern of the main
antenna may still be stronger than the reflection signals of
5   the radiated radar beam received therein. Via the auxiliary
antenna, practically always an interference signal will be
received that is stronger than the signal coming from a
target. It is known to extract from the target signals and
interference signals received by the two antennas the target
10   signal received by the main antenna in the main lobe, using
algorithms developed therefor; for this purpose, a so-called
nulling processor is used. It is further known, when there
are several sources of interference, to also deploy several
auxiliary antennas. To obtain maximum signal correlation and
15   the highest possible interference suppression, it is
important in these known systems that the auxiliary antennas
are arranged close to the main antenna and that they all
cover the same field of view of the main antenna. In planar
and in linear phased array antennas, this is achieved by
20   placing the auxiliary antennas in the same plane or in the
same line as the main antenna. In a CNA this is not possible
since there is not any plane containing all antenna
elements. A possible solution for suppressing interference
from an unknown interference source would be to arrange a
25   large number of auxiliary antennas around the CNA. However,
each auxiliary antenna requires its own receiver with pulse
compression facility, Doppler processing, and so forth, so
that the costs of such a solution become extremely high.
        The object of the invention is to provide a design of a
30   volumetric phased array antenna system, such that in a
relatively simple manner and at relatively low cost, an
efficient suppression of interference can be realized in it.
        To achieve this object, according to the invention, the
volumetric phased array antenna system such as described in
35   the preamble is characterized in that the antenna elements
are arranged in mutually spaced conformal curved virtual

surfaces having the same center of curvature or the same centers of curvature, with each combination of antenna elements in one or more surfaces together forming a volumetric phased array antenna or a part thereof.

Insofar as these surfaces have one and the same center of curvature, the virtual surfaces referred to form spherical shells or parts thereof. Thus, for instance, six of such spherical shells can be present, with each spherical shell potentially containing tens to hundreds of antenna elements. When these spherical shells are numbered 1 to 6 from the perimeter to the center, it holds, for instance, that the antenna elements in the outermost shell (shell 1) form an antenna for a weak and narrow beam, that the antenna elements in the innermost shell (shell 6) form an antenna for a weak and wide beam, that the antenna elements in, for instance, the outermost four shells (shells 1-4) form an antenna for a strong and narrow beam, and the antenna elements of the innermost four shells (shells 3-6) form an antenna for a strong and wide beam. It will be clear that all kinds of combinations of shells are possible. Thus, for instance, a main antenna can also be obtained by combining the antenna elements in the shells 1-5, and for the purpose of interference suppression an auxiliary antenna can be obtained by combining, for instance, the antenna elements in the shells 5 and 6. In all of these combinations, it is also possible, as in the planar array systems, to generate antenna patterns with several beams oriented in different directions.

The antenna elements located on the same virtual surface are connected via a T/R module to a single combination unit, while for an antenna pattern to be formed, a number of these combination units are connected to a further combination unit. If the antenna elements are to form, for instance, two antenna patterns where conventionally two discrete antennas would have to be used, two of such further combination units will be present. In

this way, it is possible to form a fixed combination of
antenna patterns, for instance a main antenna pattern and,
for the purpose of interference suppression, two auxiliary
antenna patterns. In such a situation, separate radar
5   receivers for frequency down-conversion and detection of the
radar signals will be connected to the further combination
units, whereafter the thus detected signals can be further
processed in a nulling processor. More difficult is the
situation where the choice of the number of antenna patterns
10   to be formed and the properties thereof has not been fixed.
The further combination unit is then formed by a matrix
switching unit for forming a number of antenna patterns that
is to be set as desired, with beam properties that are to be
set as desired. This measure therefore means that the
15   discrete combination units are grouped as desired. This
choice can naturally depend on, for instance, the extent of
interference suppression in the nulling processor. A
consequence of this setup, however, is that the discrete
combination units must be connected directly to a radar
20   receiver for frequency down-conversion and detecting the
radar signals before these are fed to the matrix switching
unit, which may render the costs of the entire radar system
high again, after all. In practice, however, in, for
instance, an interference suppression system with a main
25   antenna pattern and one or two auxiliary antenna patterns, a
fixed grouping of combination units will suffice.
       Through the measures according to the invention, the
following further advantages are obtained. Because the main
antenna and auxiliary antennas are assembled into one
30   integrated whole, this enables proper correlation of the
signals obtained via these antennas, and hence proper
interference suppression. The number of auxiliary antennas
can be set as desired. The auxiliary antennas can be chosen
so as to yield, to a considerable extent, the same antenna
35   gain in all directions and hence equal interference
suppression in virtually all directions. When the location

of an interference source is known, the auxiliary antenna
can be given an increased antenna gain in the direction of
the interference source through steering by means of the
beam steering computer, thus enabling further improved

5   interference suppression.

In addition to being used for suppressing interference
in military and civilian radar systems, the present
invention can also be used for communication purposes.

When, for instance, in a communication system two users

10 at widely divergent distances are to be simultaneously
served from the same communication station, then, through a
different choice of combining shells of antenna elements,
two beams in the direction of the respective users can be
obtained simultaneously, such that the station is

15 sufficiently sensitive to the distant user, but does not
induce any saturation effects in the nearby user; in other
words, the dynamic range of the receiving system of the
station with an antenna construction according to the
invention can be considerably limited.

20   When, in another example, in a communication system the
service of a mobile user from a first station is taken over
by a second station, then, after the takeover by the second
station, it is possible in the first station, by means of a
nulling system therein, to make the first station

25 insensitive in the direction of the mobile user and hence in
the direction of the second station.

The invention will now be further elucidated with
reference to the accompanying drawings. In the drawings:

30   Fig. 1 shows a planar array antenna system with a main
antenna and an auxiliary antenna on either side thereof;

Fig. 2 shows the receiving pattern of the main antenna
and the auxiliary antennas in Fig. 1;

Fig. 3 shows a volumetric phased array antenna system;

35 and

Fig. 4 shows a volumetric phased array antenna system
in which the antenna elements are arranged in a shell
structure and are combined per shell.

5   Figs. 1 and 2 relate to an antenna system according to
the prior art, having a main antenna 1 and two auxiliary
antennas 2 and 3. The antennas are of the planar phased
array type and have been arranged as close to each other as
possible. Only via the main antenna 1 is a beam radiated.
10   The receiving beam pattern of the antenna 1 is represented
in Fig. 2 and comprises a main lobe 4 and a large number of
side lobes 5. The signals stemming from a target and
received within the narrow main lobe are relatively strong;
the signals from the target that are received outside the
15   main lobe rapidly decrease in strength with increasing
angular deviation. The receiving beam pattern 6 of the
auxiliary antennas covers the entire field of view of the
main antenna, and with increasing angular deviation the
received signals from the target decrease only very little
20   in strength. In addition, in Fig. 2 an interference source 7
is indicated. The signals stemming from the target and the
signals stemming from the interference source are received
by both the main antenna and the two auxiliary antennas and,
in receivers not shown, subjected to frequency
25   down-conversion and detected. The signals obtained are
processed in a processing unit, in particular a nulling
processor 8, whereby the unwanted interference signals are
suppressed.

As already mentioned earlier, such a system does not
30   straightforwardly work in the case of a volumetric phased
array antenna. Such an antenna is depicted in Fig. 3. In
this figure, only a limited number of spatially positioned
antenna elements 9 are represented. In practice, this number
will be much greater, even up to many thousands. The antenna
35   elements 9 are disposed above a base 10. The support of the
antenna elements is here formed by coax connections 11.

Through these coax connections, each antenna element 9 is
connected to a T/R module 12. These T/R modules in turn are
connected to a transmitter 13 and a receiver 14. Signals are
transmitted via the transmitter 13, the T/R modules 12 and
5   the antenna elements 9 connected thereto, and signals are
received via the antenna elements 9, the T/R modules 12 and
the receiver 14. In the presence of the interference source
7 of Fig. 2, both signals reflected by the target and
signals coming from the interference source are received. To
10   still enable the interference signals to be suppressed, use
is to be made again of discrete auxiliary antennas as
indicated in Fig. 1, unless special measures are taken.
These measures require a special manner of positioning the
antenna elements 9. According to the invention, therefore,
15   the antenna elements are disposed, in the present exemplary
embodiment, so as to lie on concentric virtual surfaces of a
sphere; these surfaces of a sphere are hereinafter referred
to as shells. In Fig. 4, four of such shells 15-18 are
indicated. When the total number of antenna elements runs up
20   to many thousands, the number of shells can also be
considerably greater. To each of the antenna elements, again
a T/R module 12 is connected. The T/R modules of the antenna
elements 9 belonging to a shell are connected to a
combination unit. Accordingly, there are as many combination
25   units as there are shells. In Fig. 4, only the combination
units 19 and 20 are represented, which are connected to the
T/R modules for the antenna elements 9 in the shells 15 and
18. A transmitting signal is transmitted by the transmitter
13 via the distributing unit 21, the T/R modules 12 and the
30   antenna elements 9. The signals received via the antenna
elements 9 and the T/R modules 12 are combined per shell in
the combination units. In the matrix switching unit 22, the
information from the separate units is combined. For
obtaining a beam pattern for a main antenna, for instance
35   all shells are combined in the matrix switching unit 22.
This means that the signals of all combination units

together represent the signal received by this main antenna.
This signal is fed to the main antenna receiver 23 to be
frequency converted and detected. For obtaining an auxiliary
antenna, for instance the shells 17 and 18 are combined in

5   the matrix switching unit 22. This means that the signals of
only two combination units together represent the signal
received by this auxiliary antenna. This signal is fed to
the auxiliary antenna receiver 24 to be likewise frequency
converted and detected. The thus detected signals are fed

10   from the receivers 23 and 24 to the nulling processor 8 for
suppressing any interference signals. Although in this
exemplary embodiment the matrix switching unit 22 is
tailored to a fixed shell combination, it can also be set
each time, viz. by each time selecting a discrete antenna

15   pattern tailored to a specific application, through a
corresponding combination of shells. Given a large number of
shells, a great multiplicity of combinations of shells are
possible. In that case, it is more favorable to arrange a
receiver at the output of each combination unit, and to

20   combine the frequency converted and detected signals in the
matrix switching unit 22.

          The invention is not limited to the embodiment
described with reference to Fig. 4, but comprises all kinds
of modifications thereof, naturally insofar as they fall

25   within the scope of protection of the following claims. It
is noted here that the nulling processor forms part of a
signal processing unit, in which in addition to interference
suppression further video signal processing can take place.

CLAIMS

1.   A volumetric phased array antenna system comprising a
number of antenna elements, each of which is connected to a
T/R (transmitter/receiver) module, which is under the
control of a beam steering computer (BSC), to which T/R

5   module a transmitting signal is fed for forming a
transmitting beam, and via which T/R modules RF signals are
received and via a radar receiver are fed to a signal
processing unit connected thereto, characterized in that the
antenna elements are arranged in mutually spaced conformal

10   curved virtual surfaces having the same center of curvature
or the same centers of curvature, with each combination of
antenna elements in one or more surfaces together forming a
volumetric phased array antenna or a part thereof.

2.   A volumetric phased array antenna system according to

15   claim 1, characterized in that the antenna elements located
on the same virtual surface are connected via a T/R module
to a single combination unit.

3.   A volumetric phased array antenna system according to
claim 2, characterized in that for an antenna pattern to be

20   formed, a number of combination units are connected to a
further combination unit.

4.   A volumetric phased array antenna system according to
claim 3, characterized in that the further combination unit
is formed by a matrix switching unit for forming a number of

25   antenna patterns to be set as desired, with beam properties
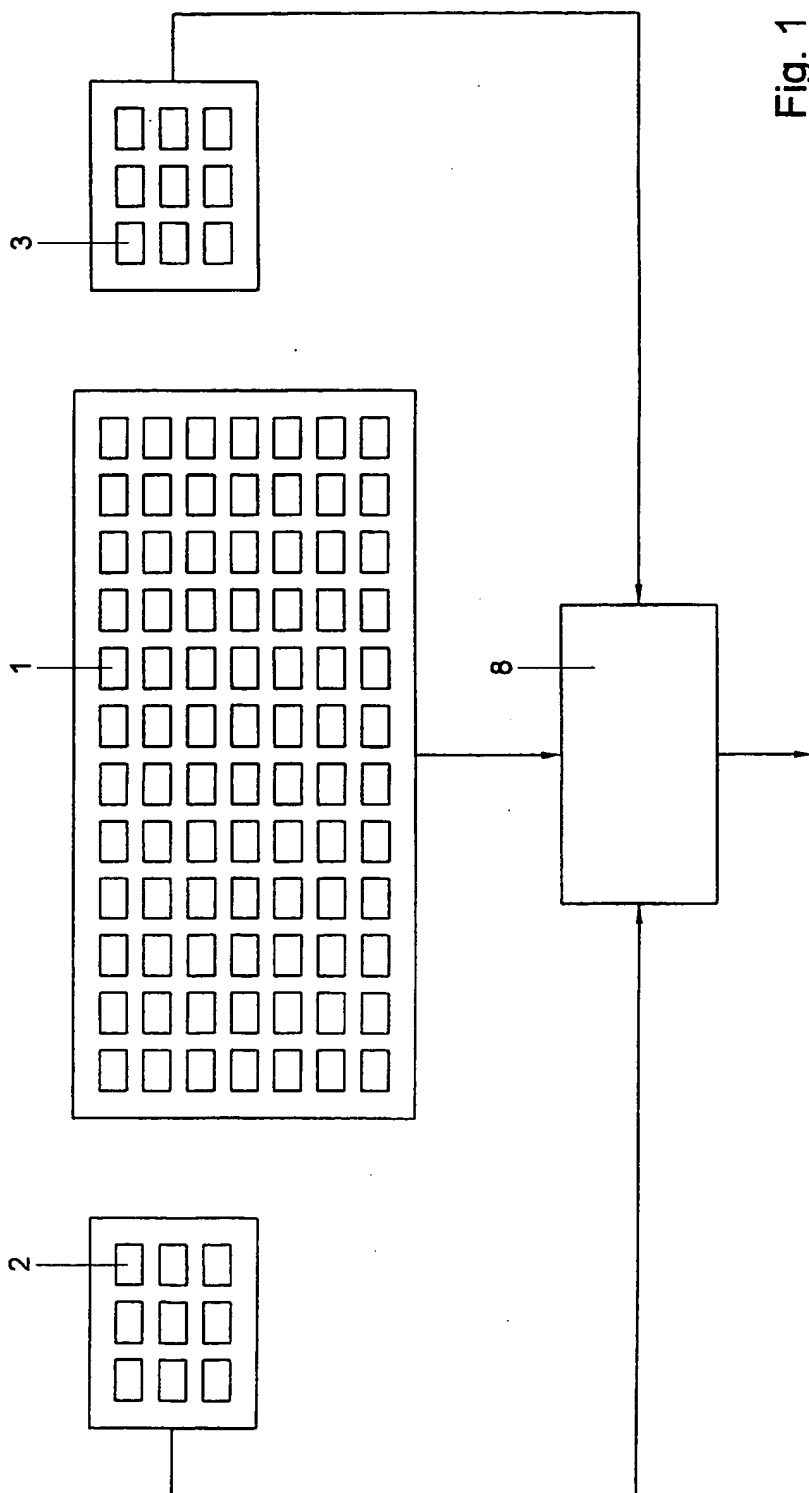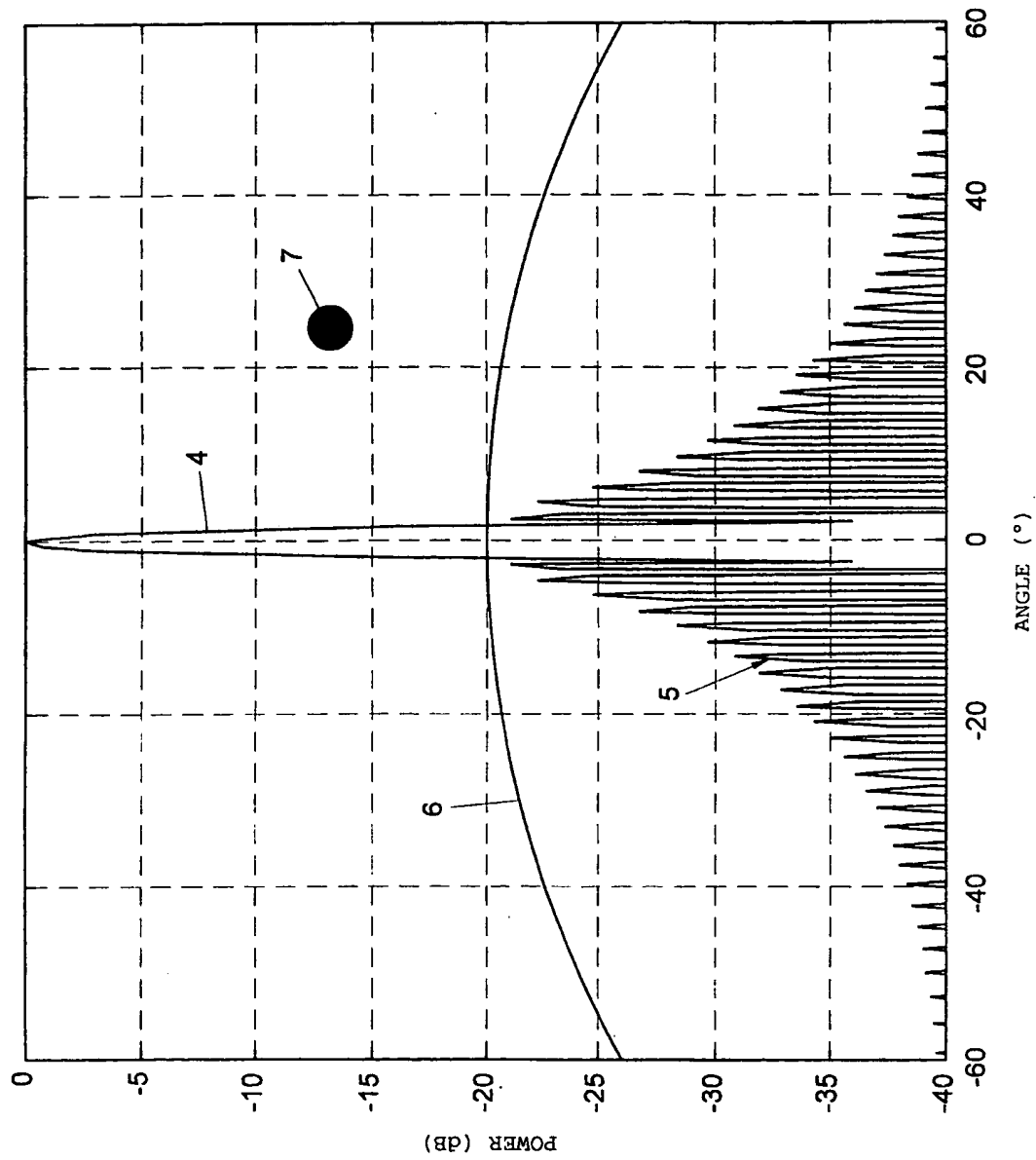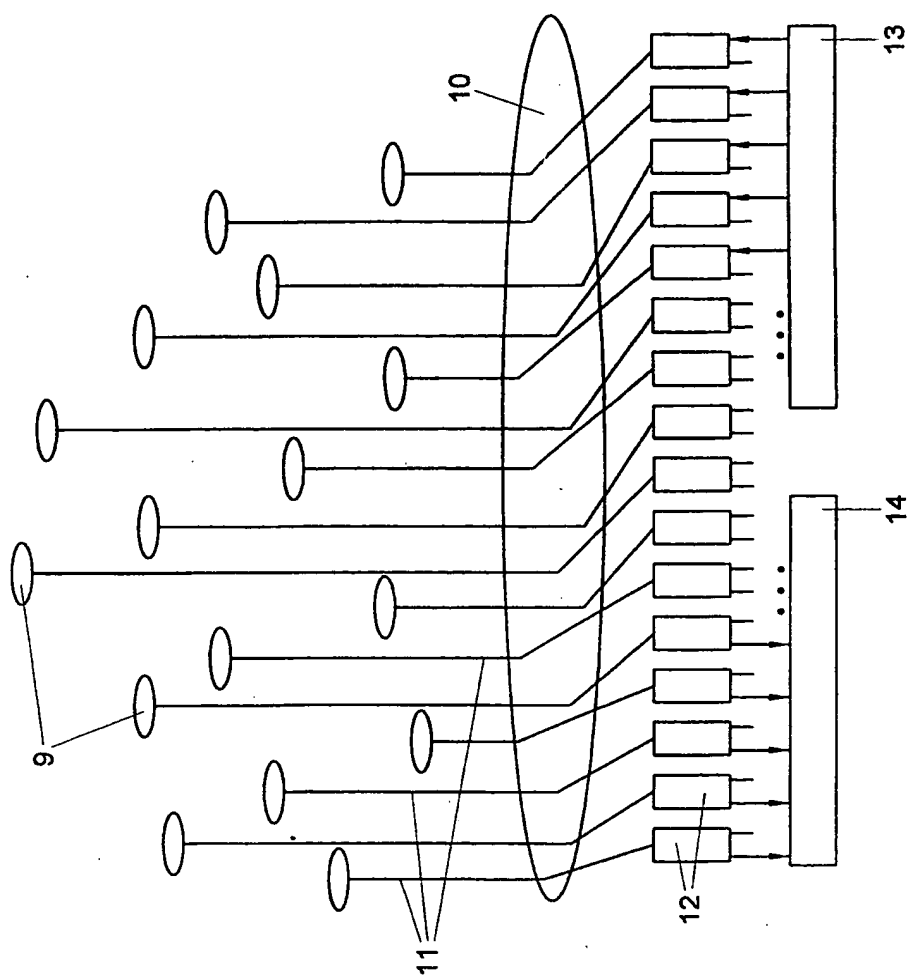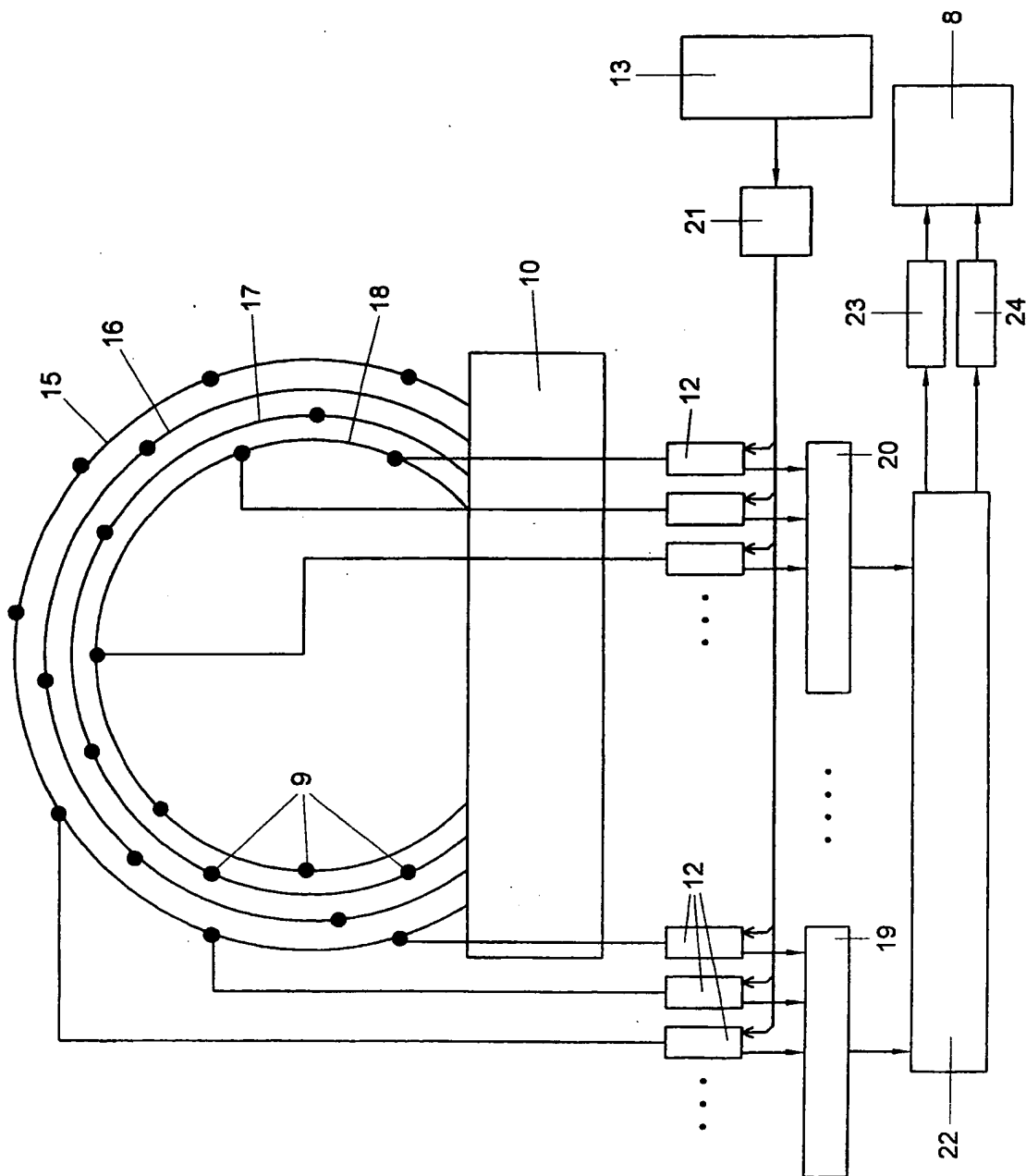to be set as desired.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H01Q21/20   H01Q3/26   H01Q21/06   H01Q21/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WILDEN H: "The crow's-nest radar-an omnidirectional phased array system" IEEE 1980 INTERNATIONAL RADAR CONFERENCE, 28 - 30 April 1980, pages 253-258, XP002118329 Arlington, VA, USA the whole document	1,2
A		3,4
Y	US 3 152 330 A (CHATELAIN M G) 6 October 1964 (1964-10-06) the whole document	1,2
A		3,4
A	US 5 038 149 A (AUBRY CLAUDE ET AL) 6 August 1991 (1991-08-06) column 4, line 44 -column 6, line 25; figures 1,2	1

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[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 May 2000	15/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Van Dooren, G

INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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